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INVESTIGATIONAL REPORT No. 15

THE SOUTH AFRICAN PILCHARD

(Sardinops ocellata)

DEVELOPMENT, OCCURRENCE AND DISTRIBUTION OF EGGS AND LARVAE, 1950-51

BY

D. H. DAVIES, M.Sc.

(Senior Professional Officer)

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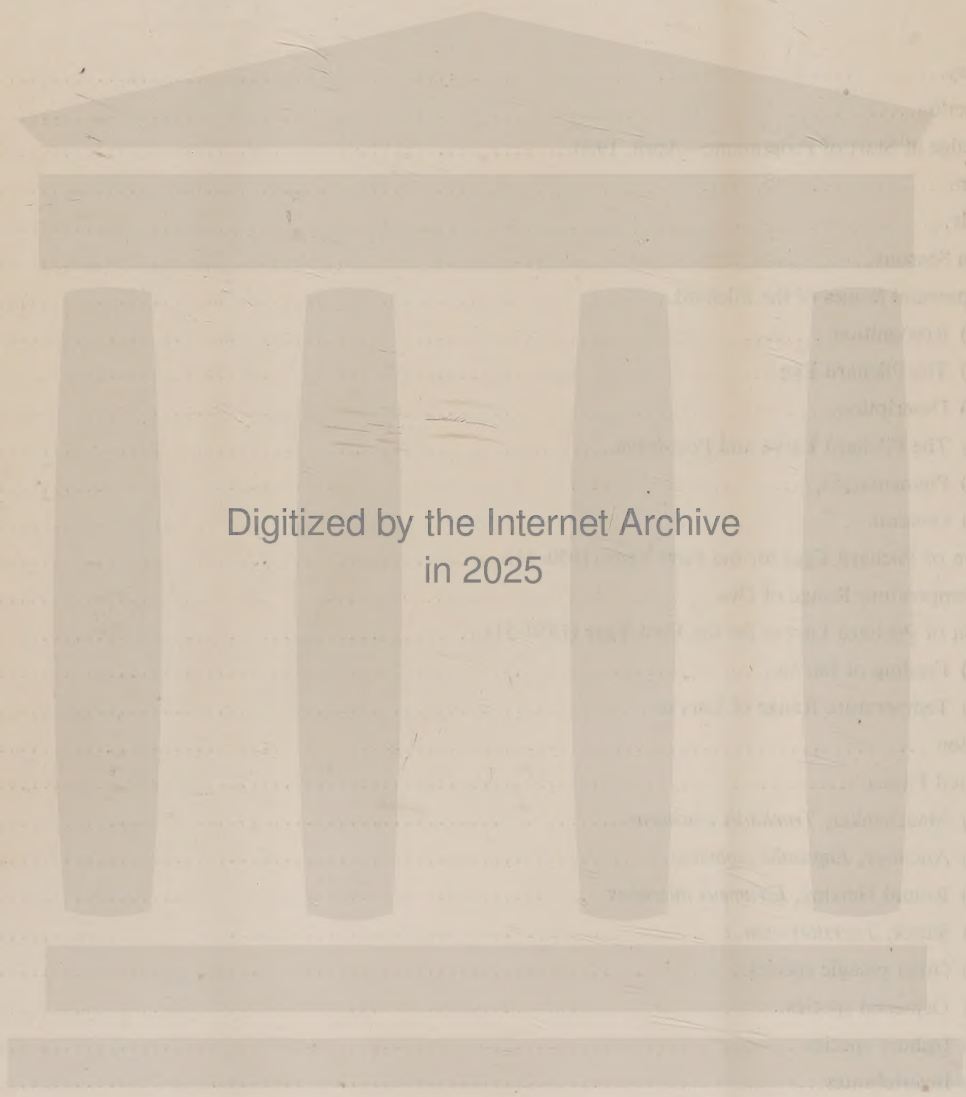

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1. SUMMARY.

This paper is the first of a series dealing with the life history of the South African Pilchard, *Sardinops ocellata* (Pappe), and consists of a brief introduction followed by a section dealing with the knowledge of the pilchard at the time of the start of the pilchard research programme in April, 1950. The problem itself is discussed and a description of the methods used is given.

In dealing with the development of the pilchard, the recognition features of the egg and larva are given and the means by which their certain identity was initially established. Then follows a description of the egg, larva, post-larva and early juvenile stages together with the location of eggs and larvae for the first year of work, March, 1950 to March, 1951. Brief mention of the feeding of larvae is made and the distribution of eggs and larvae is discussed in relation to area, time of year, spawning season of the pilchard, temperature range, etc.

As this is an introduction to the biology of the South African pilchard, it was felt that some mention of the fauna of the area should be made, and therefore a preliminary description of the fauna associated with the pilchard is given in relation to fish, including young stages and adults, certain invertebrates such as squid, and predatory sea birds. Any habits or aspects of behaviour which were felt to be of importance in relation to the pilchard, for example, the migration of snoek, are included.

2. INTRODUCTION.

The South African pilchard *Sardinops ocellata* (Pappe) has increased steadily in importance as a commercial species since the first factory started operations on the West coast at Lamberts Bay in 1943. The total catch of pilchards for the season 1943–44 was in the neighbourhood of 5,500 tons. There are now (1952) twelve large factories in operation along the western seaboard of the Union and these produced meal, oil and canned pilchards from the seasonal catch of nearly 190,000 tons of fish.

Up till 1950 very little was known of the general biology of this pelagic species, and a programme of research was therefore drawn up and work started in April of that year with the initial object of collecting data on the general biology and environment of the pilchard, in order that ultimately the reconstruction of its life history could be made. At this time the numbers of tons of pilchards caught were increasing month by month, and it became a matter of urgency that some facts be found out about the fish in order that they might be used as a basis for control measures. The possibility of overfishing the stock had to be constantly borne in mind in view of the tremendous fluctuations seen in the Californian sardine population, which had been ascribed among other factors to overfishing.

On attainment of the initial object, and being in possession of the main facts about the life history of the pilchard, it was intended that the work should be continued on lines which would eventually enable predictions of good and bad years to be made. In this manner it was hoped that reliable forecasts of pilchard fishing years could be made two and three years in advance, thus enabling the whole industry to work under optimum conditions without fear of depleting the stock.

3. KNOWLEDGE AT START OF PROGRAMME—APRIL, 1950.

Although little was known about the pilchard at the time the research programme was drawn up, the following facts were on record and could be used as a general basis:—

(1) Adult male and female pilchards were found in large numbers in the St. Helena Bay area off the West coast.

(2) They were caught by commercial fishing vessels mainly during the period March to November and were generally absent from or scarce in the area during the period December to February.

(3) Preliminary examination of samples of pilchards carried out by the Division in 1946–47 revealed that most of the fish caught commercially were sexually mature, and that gonad activity was greatest in the period August to October.

(4) At no time were ripe and running female fish obtained.

(5) During the summer months pilchard shoals were inclined to move offshore. This was shown by the fact that commercial catches were reported to be made further offshore, and further illustrated by the fact that small catches of pilchards were made during this period by trawlers fishing in the deeper waters of the trawling grounds.

(6) During summer pilchard shoals were reported to be present from time to time in False Bay.

(7) In winter very large shoals of pilchards were known to appear regularly off the East coast in the vicinity of Port St. Johns from where they moved up the coast of Natal as far as Durban where they disappeared.

4. PROBLEM.

The main commercial pilchard fishing grounds of the Union of South Africa lie off the West coast and are centred in St. Helena Bay. Most of the catches are made in the area of sea bounded by Cape Columbine in the south, Rooiduinepunt in the north and extending 35 miles seawards from a point midway between the two (see Fig. 1).

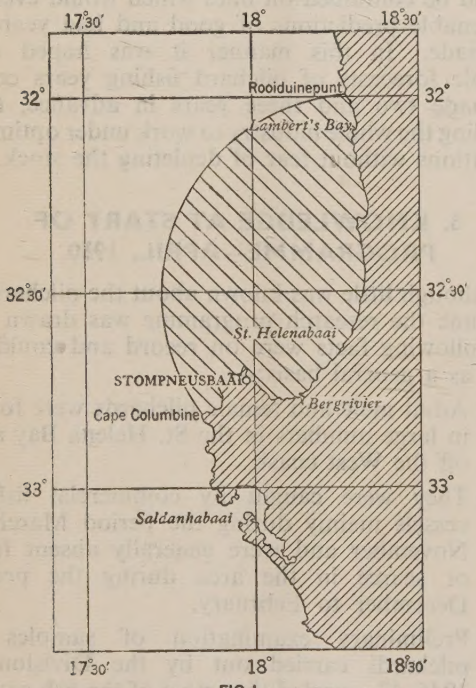

FIG. I

MAIN COMMERCIAL FISHING GROUNDS

Trigonometrical Survey, 1954. Government Printer, 1954

This being the focus of pilchard activity, a network of stations was planned which would cover the area. These stations were worked twice a month by R.S. "*Africana II*". Their general arrangement and exact positions are shown in Fig. 2 (routine stations). At each station a record of plankton, salinities, temperatures and phosphates was made with the object of ascertaining the occurrence and distribution of pilchard eggs, larvae and juveniles, the organisms found in association with them, such as food organisms, and the hydrological or environmental conditions in which these and adult pilchards exist. From this it was hoped that the main spawning area or areas of the pilchard would be discovered, and the temperature range of spawning, the food requirements of developmental stages, their rate of growth and their distribution and dispersal in relation to temperature, salinity, wind and current determined. A closer net-work of stations, at which plankton nets were worked and surface temperatures were taken, was drawn up to cover St. Helena Bay in detail [see Fig. 2 (Inshore stations)].

5. METHODS.

Three vessels were used in the pilchard research programme, the R.S. "*Africana II*", R.V. "*Schipa*" and P.B. "*Palinurus*".

R.S. "*Africana II*" is a modern research ship of 1,300 tons displacement built in the United Kingdom in 1950. A full description of this ship has been published (Marchand, Shannon and Clark, 1951). The plankton nets and scientific gear used in "*Africana II*" were standard and identical to those used in R.R.S. "*Discovery II*". Full descriptions of all gear mentioned together with methods of operation are available in *Discovery* Reports (Kemp, Hardy and Mackintosh, 1929).

R.V. "*Schipa*" is a modified ex-naval rescue launch of total length 108 feet, and with a cruising speed of 12 knots. This vessel was used for patrolling and surveying the rock lobster sanctuaries of the Cape Peninsula, and for research duties relative to the inshore stations in St. Helena Bay of the pilchard research programme. The "*Schipa*" was fitted with a small deck laboratory and towed plankton nets and took a surface water temperature at each station.

P.B. "*Palinurus*" is a patrol boat of total length 50 feet, built on the design of a typical Cape fishing cutter. Although entirely without any laboratory facilities, the "*Palinurus*" was able to work the tow-nets and take temperatures on the round of inshore stations every month in a very satisfactory manner. The "*Palinurus*" has a cruising speed of 9 knots.

In practice each of the smaller vessels did the round of inshore stations once per month.

The following standard routine procedure for the pilchard research stations was adopted:—

I. Routine stations done by "*Africana II*"—procedure at each station—

(*a*) *Biological.*

(1) N70V plankton tow net haul from 100–0 metres.

(2) N50V plankton tow net haul from 100–0 metres (selected stations only).

(3) N100H plankton tow net haul at 0 metres for 10 minutes.

(4) N100H plankton tow net haul at 100 metres for 10 minutes.

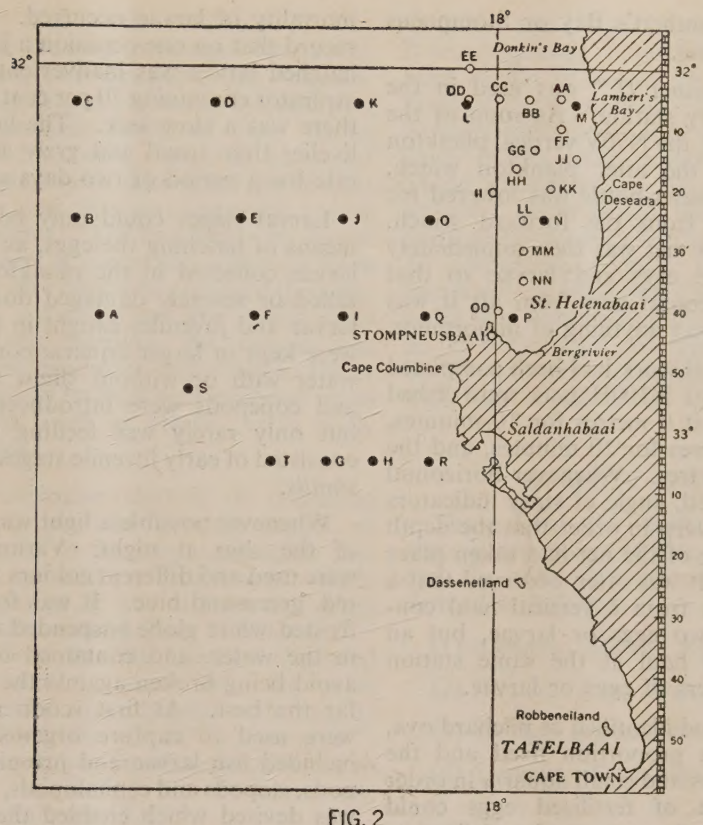

FIG. 2

● ROUTINE STATIONS : "AFRICANA II"

○ INSHORE STATIONS : SMALL VESSELS

Trigonometrical Survey, 1954. Government Printer, 1954.

(5) N100B plankton tow net haul 150–0 metres.

(6) N200 (YFT)—selected stations only (usage discontinued at an early stage due to poor results).

(*b*) *Hydrological.*

(1) Temperatures and water samples taken at the following depths: 0, 10, 20, 30, 40, 50, 60, 80, 100, 125, 150, 175, 200, 250, 300, 400 metres.

(2) Bathythermograph record down to 270 metres.

(3) Continuous thermographic record of surface temperature throughout routine cruise.

(*c*) *Meteorological.*

Four hourly weather observations throughout every cruise and at each station.

II. Inshore stations done by R.V. "*Schipa*" and P.B. "*Palinurus*"—procedure at each station—

(*a*) *Biological.*

(1) N70H plankton tow net haul at 0 metres for 10 minutes.

(2) N50H plankton tow net haul at 0 metres for 10 minutes (selected stations only).

(*b*) *Hydrological.*

(1) Temperature at 0 metres.

(*c*) *Meteorological.*

(1) Weather observations at each station.

As the small vessels did not normally carry a biologist, all plankton samples were fixed immediately after collection, carefully labelled and placed in jars and taken to one of the shore bio-

logists stationed at Lambert's Bay or Stompneus Bay for detailed analysis.

The gear on "*Africana II*" was used in the same sequence at every station. As soon as the ship became stationary, the N70V vertical plankton net was lowered on the after plankton winch. At the same time the water-bottle was lowered for hydrological samples from the forward winch. The catch of the N70V net was then immediately examined for pilchard eggs and larvae so that before using the horizontal nets from aft it was known whether to expect anything of importance.

After the hydrological work had been completed forward, the horizontal N100H nets were fished from aft, the N100H at 0 metres for 10 minutes, the N100H at 100 metres for 10 minutes, and the N100B from 150–0 metres. Whenever horizontal plankton nets were used, angle of stray indicators were attached to the warp in order that the depth at which actual fishing of the net had taken place could be calculated. It was often observed that a collection of plankton from a vertical haul contained only one or two eggs or larvae, but an oblique or horizontal haul at the same station contained large numbers of eggs or larvae.

If eggs were found and identified as pilchard ova, a count was made, a proportion fixed and the remainder placed in jars and small aquaria in order that the development of fertilized eggs could continue. These were then removed and fixed at regular intervals. Eggs were placed in aquaria with running sea water, aquaria with fine aeration and in smaller glass containers without aeration or circulation. It was found that eggs placed in running sea water were more liable to suffer extensive temperature change and also tended to accumulate in one corner of the aquaria in a mass in which individual eggs constantly rubbed against each other apparently causing mechanical damage. Aeration also tended to cause bunching of eggs and excessive movement. By far the most successful method of keeping eggs was to place small numbers in glass jars containing filtered sea water (from the station at which they were collected) on a gimbal table. Five hundred cc. of water were placed in a jar of one litre capacity in the proportion of 5 eggs to a 100 cc. of water. The larvae were treated in exactly the same manner, and it was found that recently hatched larvae and early stages were far more likely to develop under non-crowded conditions in small containers placed on a gimbal table and without aeration or water circulation. A drawback to this method was that an increase in temperature could not be avoided, but by maintaining a constant circulation of air in the laboratory no great increase took place and no mortality of larvae occurred. It is of interest to record that on one occasion a jar containing newly hatched larvae was inadvertently placed under an aspirator containing 70 per cent alcohol from which there was a slow leak. The larvae became much livelier than usual and grew at twice the normal rate for a period of two days and then died.

Larval stages could only be obtained alive by means of hatching the eggs, as all larvae and post larvae collected in the plankton nets were either killed or severely damaged during capture. Post larvae and juveniles caught in traps or scoop nets were kept in larger aquaria containing filtered sea water with or without slight aeration. Diatoms and copepods were introduced as food material but only rarely was feeding observed and that consisted of early juvenile stages feeding on *Oithona similis*.

Whenever possible a light was used over the side of the ship at night. Various light intensities were used and different colours were tried including red, green and blue. It was found that a 40 watt frosted white globe suspended over the ship's side in the water, and contained in a wire basket to avoid being broken against the ship's side, was by far the best. At first scoop nets on long poles were used to capture organisms present, which included fish larvae and juveniles, worms, amphipods, isopods and cephalopods, but later a platform was devised which enabled the biologist to stand at the level of the surface of the water and use a short-handled scoop net with much greater ease and effectiveness.

Many valuable specimens were obtained by this means, and in fact for a long time it was the only method by which juvenile pilchards were collected. All attempts to catch them with the N200 net failed as they were apparently able to swim fast enough to evade capture. Later, however, large numbers of juvenile pilchards were obtained by means of explosives.

The main drawback to the method of using a light and scoop net at night was weather. It was found to be impossible under all but the best conditions of sea.

The explosive method of catching small fish was suggested by that used in the Californian research scheme and was carried out as follows:—

When signs of small fish were seen, a boat was immediately lowered. With the boat moving slow ahead a charge was thrown a few feet from the stern. As soon as the explosion had taken place the boat was turned and brought round to the spot where the explosion occurred and the fish collected by means of scoop nets. The charge found to be

most suitable for this work consisted of two standard industrial blasting cartridges containing a charge of 60 per cent gelignite, tied together securely with string with a detonator inserted and attached to a convenient length of fuse. Three to four inches of fuse were found to be useful lengths for the explosion to take place not too far below the surface, but this was naturally varied with the depth of water. The fuse was lit by means of a standard igniter in a position sheltered from the wind and great care had to be exercised throughout the operation. If there was any doubt as to whether a fuse was burning, the charge was immediately thrown overboard and away as far as possible. Fuse had to be kept well wrapped up in watertight material, such as plastic, as it easily became damp at sea.

Although the explosive method of collecting samples of late larval and juvenile stages of pilchards was found to be very successful, and depended mainly on correct location of shoals before using the charge, it was difficult and often impossible to use this method from "*Africana II*" The main reason was that the juveniles appeared to congregate in shallow water near the coast in bays and protected areas behind reefs usually inaccessible to a ship of the size of "*Africana II*". The bulk of this work was therefore transferred to the two smaller vessels of the Division, viz. "*Schipa*" and "*Palinurus*".

Apart from catching these stages with the aid of a light, platform and scoop net from "*Africana II*", a floating fish larva trap similar to that designed and used in the California co-operative sardine research programme (Cal. Co-op. Sard. Res. Comm., Progress Report, 1950) was used with considerable success. This larva trap was put into operation whenever the ship was stationary at night, but it was found that it could only be used successfully when the weather and sea conditions were calm. Slight wind or sea caused excessive movement of the trap and organisms attracted to the light were unable to enter the holes. Also with a small degree of motion on the part of the ship, the trap was liable to suffer damage by bumping against the ship's side.

The larva trap was usually used from a davit amidships, but when more convenient could be used from a davit aft. Approximately 80 feet of rope and rubber insulated flex were used so that the trap could float well away from the ship's side to perfectly calm water unaffected by the ship's wash. Apart from the larvae and juveniles of a number of species of fish, polychaetes, isopods, amphipods, euphausiids and arrow-worms, small medusae and large copepods were also caught. It was frequently found that the different organisms were caught in succession during the night. For example, on a particular night juvenile fish of one or more species would be caught in large numbers from shortly after sunset until 2100 when they would disappear, to be replaced by polychaete worms. These would then decrease in numbers and another wave or succession, this time consisting of amphipods, would appear. Although this succession of organisms appearing in chronological order was frequently noticed, no fixed pattern has so far been found although the varied appearance of the different organisms is likely to be linked with local conditions of wind, tide and moon.

6. NOTE ON SEASONS.

Throughout the pilchard research work the seasons are described as summer, autumn, winter, etc. In order to avoid confusion the seasons are defined as follows:—

(1) *Autumn:* March, April, May.

(2) *Winter:* June, July, August,

(3) *Spring:* September, October, November.

(4) *Summer:* December, January, February.

7. DEVELOPMENTAL STAGES OF THE PILCHARD.

(i) Recognition.

During the course of regular examination of pilchard samples taken from commercial catches at the shore stations, a detailed study was made of the gonads of all fish. Each gonad was weighed, sexed, assigned an index of maturity and in the case of female fish, ova diameters of a smaller sample were measured. In this way the recognition features and dimensions of a pilchard egg were established at an early stage in the research programme. In order to illustrate this, a table of mean monthly ova diameters for the first year is shown below. The analysis and discussion will, however, be considered elsewhere together with other factors relating to maturity, spawning season and reproduction in general.

It may be mentioned in relation to the table of ova diameters that eggs were selected for measurement from the posterior end of the ovaries in an area representing approximately one third of the total area of the gonad. This procedure was adopted due to the fact that the other two thirds of

TABLE I.

OVA DIAMETERS.

No.	Month and Year.	Number of Fish.	Number of Ova Measured.	Mean Ova Diameter.
				mm.
1.....	March, 1950.....	5	250	0·614
2.....	April, 1950.....	24	1,200	0·537
3.....	May, 1950.....	12	600	0·553
4.....	June, 1950.....	13	650	0·576
5.....	July, 1950.....	15	750	0·577
6.....	August, 1950.....	65	3,250	0·639
7.....	September, 1950.....	35	1,750	0·633
8.....	October, 1950.....	1	50	0·608
9.....	November, 1950.....	65	3,250	0·654
10.....	December, 1950.....	15	750	0·710
11.....	January, 1951.....	5	250	0·933
12.....	February, 1951.....	10	500	1·108

the ovaries of most female pilchards contained ova in a much less advanced state of development and it was felt that measurement of these would not be of significance in relation to impending spawning activity.

In only one case was a ripe and running female pilchard obtained, and unfortunately no male was available at the time for artificial fertilization. This female was caught in St. Helena Bay in the month of February in a set net together with a number of mullet (*Liza ramada*) and one other female pilchard. The mean ova diameter of discrete transparent ova in this fish was 1·17 mm. measured with a micrometer eyepiece after fixation in 5 per cent formalin. It will be seen from the table that nine other fish were obtained in the month of February all of which were in a fully ripe but not running condition, giving a mean ova diameter of 1·108 mm.

Having established the characteristics of the pilchard egg at the pre-spawning stage, it was not difficult to identify and select eggs from the plankton in developmental sequence from this time to the time of hatching. The recognition features of the early larvae were found by hatching fertilized eggs collected in the plankton nets at sea in the laboratory of "*Africana II*". From these early larval stages it was possible to "build on" until a developmental series up to the juvenile fish was obtained. This was a protracted business mainly because of the small numbers of eggs and larvae obtained in the first year. The pigmentation of the larvae was found to be the most important recognition feature.

(ii) The Pilchard Egg.

(See Pl. 5, Figs. I, II and III.)

The ripe ovum before spawning had a diameter of 1·17 mm. and an oil globule diameter of 0·18 mm. Developing eggs taken from plankton tow nettings at sea were found to have a range of ova diameters from 1·48 mm. at the blastodermal cap stage to 1·91 mm. just before hatching. The mean ova diameter for all pilchard eggs taken in the plankton nets for the first year (total number 6,482) was 1·70 mm. The mean oil globule diameter was 0·18 mm.

The egg of the South African pilchard is very similar in general appearance to that of the California sardine (*Sardinops caerulea*), the main differences being dimensional. According to Miller (1952) the ova diameter of the California sardine at the time of fertilization is 1·15 mm., while that of the South African pilchard just prior to spawning is 1·17 mm. At the blastodermal cap stage the ova diameter of the California sardine is 1·38 mm. while that of the South African pilchard is 1·48 mm. Miller found that "water hardening" was complete 10 hours after fertilisation and that the ova diameter of the California sardine remained constant at 1·83 mm. The period of "water hardening" for the South African pilchard is not known, but while numbers of eggs possessed a mean ova diameter of 1·80 mm.

at the time of hatching, a few others in an isolated group were found to have an ova diameter of 1·91 mm. just prior to hatching. The diameter of the oil globule in the California sardine is 0·16 mm., while that of the South African pilchard is 0·18 mm. In general, therefore, the ovum of the South African pilchard was found to be larger than that of the California sardine.

(iii) Description.

The egg is spherical with a smooth, transparent vitelline (fertilisation) membrane and a large perivitelline space. The yolk is small and irregularly segmented and gives the impression of a mosaic pattern. There is a single oil globule of diameter 0·18 mm. The diameter range of the egg from just before spawning to time of hatching is 1·17 mm.–1·91 mm., but the mean ova diameter for all eggs collected at sea was 1·70 mm.

The blastodermal cap is large, rounded and in appearance much darker and more dense than the yolk. Throughout development the egg remains buoyant and floats at the surface.

The larva develops rapidly and the somites are easily visible. Just before hatching it is much elongated and very lively. A double row of black pigment spots or melanophores extends from the dorsal region of the head of the larva along its entire length on either side of the dorsal fin.

(iv) The Pilchard Larva and Post-larva.

After hatching the larva is held to the surface in an inverted position by the yolk sac and oil globule. At first it floats helplessly but soon begins to swim with short bursts of rapid tail movement. After each burst, however, it returns to the surface. The total length of the larva immediately after hatching is 3·6 mm. (mean length of 3 individuals only).

(v) Pigmentation.

From the examination of a number of larvae after hatching it was evident that the dorsal melanophores migrated downwards towards the ventral surface in a manner similar to that described for the California sardine by Miller (1952). During the migration the spidery arms of the melanophores mainly disappeared and by the time they reached the ventral region they had become consolidated into much darker patches of pigment, black in colour but appearing dark brown at the edges. In the post-larva of total length 10·6 mm. (see Pl. 6, Fig. II), the melanophores were situated along and below the gut with a small number scattered in the region of and ventral to the pectoral fin, one or more just above the vent and a few scattered amongst the lepidotrichia of the caudal fin. In the late post-larva of total length 23·5 mm. (see Pl. 6, Fig. III), a definite pattern was reached in which a number of melanophores was scattered in the region of the opercle and in a lineal arrangement above the gut as far as the pelvic fin and extending beyond this point below the gut but not quite reaching the vent. Along the dorsal surface of the gut between the pelvic fin and the vent was a series of chromatophores which were much lighter in colour, and a single large dark melanophore was situated just above the vent. Concentrations of small chromatophores were situated in the basal region of the caudal fin.

(vi) General.

Shortly after hatching the lepidotrichia appeared in the caudal fin region and the first folds of the pectoral fins could be seen. At this stage (see Pl. 6, Fig. I) the head region was flexed downwards over the yolk sac and the auditory capsule was clearly visible. The head was rounded, the eye large and evidence of the development of the optic lobes was very soon seen. The yolk sac was rounded and the oil globule spherical in shape. The somites at this stage were very well defined. The dorsal, caudal and ventral fin membranes were broad and transparent and the characteristic posterior situation of the rectum and vent was apparent.

In the post-larva of total length 10·6 mm. (see Pl. 6, Fig. II) a great deal of development had taken place. The mouth was open and more fully formed. The pectoral fin was large and well shaped. The caudal fin was much more advanced but no signs of formation of a dorsal fin were yet evident. The post-larva of total length 23·5 mm. (see Pl. 6, Fig. III), had lost most of its larval characters and in appearance was much closer to the form of the adult pilchard. The fin-membrane had entirely disappeared and the dorsal, caudal, anal, pelvic and pectoral fins were formed and possessed the full number of rays. The position of the dorsal was, however, still well behind in relation to the pelvic. The general appearance of this stage was remarkably similar to that of the European pilchard *Sardina pilchardus* at 24 mm. total length, described and figured by Cunningham (1891).

Considering the state of development at the 23·5 mm. stage, and the fact that the juvenile pilchard of total length 42 mm. (see Pl. 6, Fig. IV) was adult in form, it seems likely that the metamorphosis from post-larva to juvenile takes at total length between 30–35 mm.

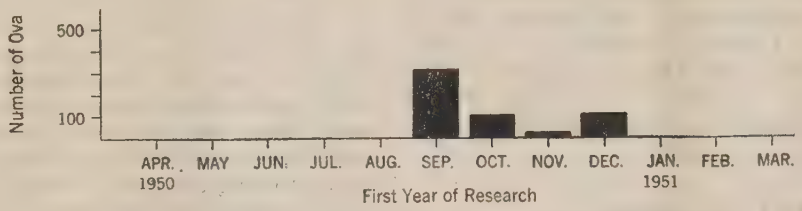

FIG.3 PILCHARD OVA — ROUTINE STATIONS

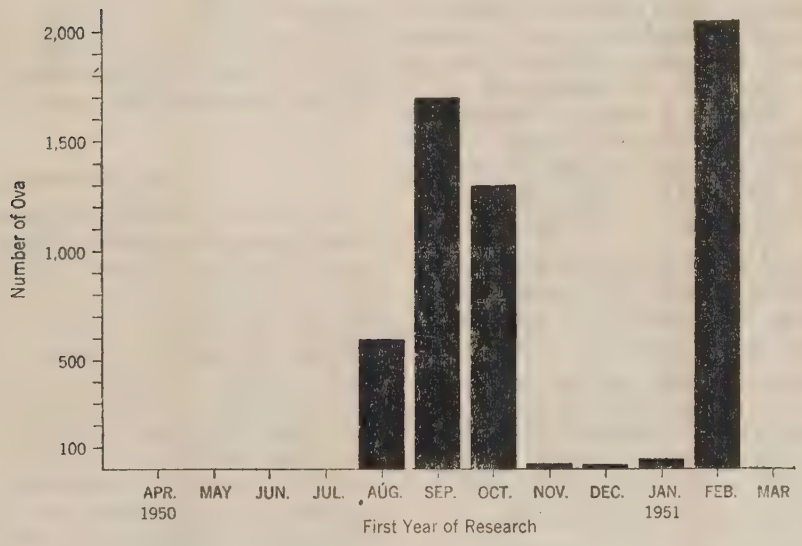

FIG.4 PILCHARD OVA — INSHORE STATIONS

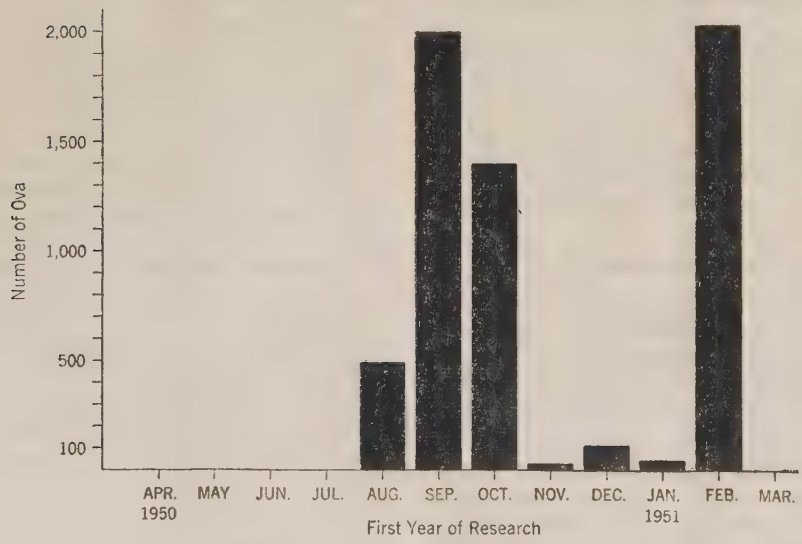

FIG.5 PILCHARD OVA — ALL STATIONS

Trigonometrical Survey, 1954.

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The juvenile (42 mm. stage) was not scaled but was otherwise adult in form.

8. LOCATION OF PILCHARD EGGS FOR THE FIRST YEAR (1950–51).

(See Figs. 3, 4 and 5 and Tables I and II.)

(a) Winter, 1950.

During the first five months of pilchard research, i.e. from March to the end of July, 1950, no spawned pilchard ova were obtained. The first recordings of eggs were made at the end of winter in the month of August and consisted of a total of 596 ova scattered throughout St. Helena Bay at most of the inshore stations (see Pl. 1, Fig. I). The eggs were found in water with a temperature range of 13·4–14·6°C.

(b) Spring, 1950.

During spring a total of 3,409 ova was recorded, 423 from the routine stations and 2,986 from the inshore stations. Eggs from the inshore stations were again scattered throughout the St. Helena Bay area but differed in distribution from the winter eggs by being more concentrated at the northern end of St. Helena Bay in the vicinity of Lamberts Bay (see Pl. 1, Fig. II). The temperature range for inshore stations where eggs occurred during this period was 12·7–17·8°C. The small numbers of eggs obtained at the routine stations were strangely isolated from the St. Helena Bay ova and occurred within a temperature range of 15·24–18·44°C.

During the spring months the highest incidence of ova occurred in September—2,001 ova—with a falling off in October—1,394 ova—and a further falling off in November when only 14 ova were recorded.

(c) Summer, 1950–51.

In summer 1950–51, a total of 2,183 ova was recorded, 102 from the routine stations and 2,081 from the inshore stations. Eggs from the inshore stations were even more concentrated in the northern area of St. Helena Bay in the vicinity of Lamberts Bay (see Pl. 2, Fig. III) than in spring. The temperature range for inshore stations where eggs occurred was 12·8–20·0°C. A small number of eggs was obtained at the routine stations, but in the same area and in fact at two of the same stations as the eggs recorded in spring. The temperature range for these eggs was 16·09–19·16°C.

TABLE II.

PILCHARD OVA AND LARVAE—ROUTINE STATIONS. ("AFRICANA II").

Month.	Mean Surface Temperature.	Temperature Range of All Stations.	Number of Ova.	Mean Ova Diameter.	Number of Larvae.
	°C.	°C.		mm.	
1950—					
April	15·61	13·09–18·90	—	—	—
May	15·39	13·69–17·92	—	—	—
June	15·61	13·08–17·47	—	—	—
July	14·58	13·08–15·86	—	—	—
August	14·54	12·77–15·56	—	—	29
September	14·75	13·56–15·57	310	1·76	43
October	16·42	14·33–18·44	108	1·75	17
November	15·30	12·54–17·61	5	1·87	102
December	15·90	12·27–18·09	102	1·81	19
1951—					
January	15·83	12·45–19·16	—	—	93
February	15·26	12·23–18·36	—	—	35
March	14·79	12·25–18·63	—	—	—

During the summer months 110 ova were recorded in December, 40 in January and 2,033 in February.

Temperature Range of Ova.

Pilchard eggs were recorded during the first year within a maximum temperature range of 12·8–20·0°C.

9. LOCATION OF PILCHARD LARVAE FOR THE FIRST YEAR (1950–51).

(See Fig. 6.)

(*a*) Winter, 1950.

During the first four months of pilchard research from April to July, 1950, no pilchard larvae were obtained. The first larvae appeared in August at the end of winter when a total of 29 was recorded at routine stations only (see Pl. 3, Fig. IV). The mean total length of these larvae was 8·9 mm., and they were well spread out and occurred in small numbers in the central area of routine stations where the temperature range was 14·06–15·26°C. No larvae were recorded at the inshore stations during winter.

(*b*) Spring, 1950.

During spring a total of 171 larvae was recorded in a temperature range of 13·05–19·01°C., 162 from the routine stations and search stations T2, T3, T9, T10, T15, T16 combined (see Pl. 4, Fig. V) and 9 from the inshore stations. The greatest number of larvae occurred in November, namely 102, while 52 were recorded in September and 17 in October. The mean total length of these larvae was 7·7 mm.

Although the total number of larvae recorded in the spring months was very small, they were distributed over a remarkably wide area (see Pl. 4, Fig. V). The north/south or coastwise extension of this area was 110 nautical miles and the east/west or seaward extension over 80 n.miles.

(*c*) Summer, 1950–51.

In summer 1950/51 a total of 147 larvae was recorded from routine stations and a single search station No. R21 within a temperature range of 12·23–18·15°C. No larvae were recorded from the inshore stations during this period. The mean total length of larvae collected was 9·2 mm. The largest number recorded was 93 in January, 35 being found in February and 19 in December.

The total number of larvae recorded during summer was very small and their distribution wide and very irregular (see Pl. 3, Fig. VI).

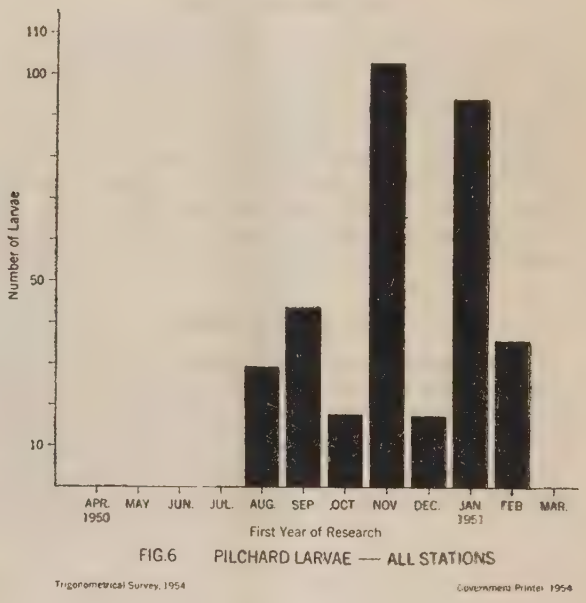

FIG.6 PILCHARD LARVAE — ALL STATIONS

(i) Feeding of Larvae.

The larvae collected during the first year were examined in relation to the presence of food organisms in the alimentary tract but in no case was anything found. In most cases they contained nothing but mucus.

In the early juvenile stages of total length 35–40 mm. remains of copepods of the genus *Calanus* were frequently found. Later stages from 40–50 mm. total length were found to have been feeding on *Calanus* and diatoms such as *Coscinodiscus* and *Rhizosolenia*, and from 50 mm. upwards contained the above diatoms together with *Thalassiosira* and *Goniaulax*.

(ii) Temperature Range of Larvae.

Pilchard larvae were recorded during the first year within a maximum temperature range of 12·54–19·16°C. with larger numbers present in water between 15–16°C.

TABLE III.

PILCHARD OVA AND LARVAE—INSHORE STATIONS. (SMALL VESSELS).

Month.	Mean Surface Temperature.	Temperature Range of All Stations.	Number of Ova.	Mean Ova Diameter.	Number of Larvae.
	°C.	°C.		mm.	
1950—					
April	13·5	12·7–14·3	—	—	—
May	14·6	14·2–15·0	—	—	—
June	12·5	13·5–14·4	—	—	—
July	13·7	13·4–13·9	—	—	—
August	14·0	13·4–14·6	596	1·59	—
September	14·4	13·9–14·9	1,691	1·61	9
October	16·0	14·4–17·8	1,286	1·64	—
November	14·6	12·7–14·8	9	1·68	—
December	16·6	12·8–16·8	8	1·59	—
1951—					
January	16·7	15·0–20·0	40	1·68	—
February	15·7	15·1–17·2	2,033	1·72	—
March	—	— No samples taken.		—	—

10. DISCUSSION.

The total numbers of eggs and larvae of the pilchard found during the first year were very small and although there was fairly wide dispersal, particularly of larvae in spring, it seems unlikely that these indications were fully representative of the main spawning area of the pilchard. From commercial catches of pilchards and from the very extensive shoals seen in the area, it seems that the St. Helena Bay region supports a very large population of pilchards. Mass spawning of such a population would presumably produce very much larger numbers of eggs and larvae.

Apart from this aspect of mass spawning, however, reproduction of the pilchard has been shown to take place in the St. Helena Bay area and to extend from the latitude of Cape Town to north of Lamberts Bay and as far as 80 n. miles seawards from the coast. It is likely that this distribution will be extended by later observations.

The spawning season began at the end of winter in the month of August and continued through spring and summer with peaks in September and February. According to the distribution of the ova collected, St. Helena Bay was the main spawning area, but in relation to larvae found and knowledge of surface currents, spawning extended over a much wider area. No larvae were found close inshore, but post-larvae and juveniles were collected close inshore in St. Helena Bay and in Saldanha Bay.

St. Helena Bay was found to be an area of great variability where currents were constantly changing in relation to local winds, upwelling, deviations due to the shape of the coastline and other factors. It is possible therefore that ova spawned in the bay were dispersed in may different directions. For example, the 1950 winter spawning was confined to the St. Helena Bay area (see Pl. 1, Fig. I), but the winter larvae were spread out offshore west of St. Helena Bay (see Pl. 3, Fig. IV), showing a movement south and west if the larvae had hatched from these ova and not from other unrecorded ova in the south. In spring spawning took place in St. Helena Bay and at three stations to the west of

Cape Columbine (see Pl. 1, Fig. II) and the larvae were dispersed over a very wide area (see Pl. 4, Fig, V). There was a similar distribution of ova in summer (see Pl. 2, Fig. II) and the larvae were also scattered over a wide area. It is possible that ova from offshore spawnings in the south are carried northwards but those which are spawned inshore in St. Helena Bay are carried south in counter-currents which are deviated to the west by the land in the vicinity of Stompneus Point and perhaps dispersed even further by the effects of upwelling. The whole question of dispersal of ova and larvae in relation to currents will be discussed in a later paper when at least two years data are available.

Pilchard ova were found within a temperature range of 12·8–20·0°C. This is a considerable range and ova kept in glass aquaria in the ship's laboratory were apparently not adversely affected when the temperature rose as high as 23°C.

From observations of pilchard shoals and from the distribution of eggs and larvae, it was evident that a southerly migration of pilchards from St. Helena Bay started in spring and continued through summer. Combined with this southerly movement was a tendency to move offshore. This did not appear to be a mass migration of all the pilchards in the area, but a gradual movement of separate shoals. Spawning occurred in these individual shoals from time to time in the whole area and the ova and larvae were carried northwards until the metamorphosis of post larvae into juveniles, at which stage they were capable of moving independently and made their way to sheltered areas such as the inshore waters of St. Helena Bay and of Saldanha Bay.

It is not certain whether the shoals of adult pilchards moved back to St. Helena Bay after spawning, as large numbers of pilchards were recorded in the Cape Point–False Bay–Cape Agulhas area in late summer, and it is possible that these consisted of fish which had recently spawned. Unfortunately no data on the gonad condition of these fish were obtained. Whether they moved further round the south coast or turned back and returned to St. Helena Bay was not established, but pilchards had returned to St. Helena Bay by the beginning of the year.

II. ASSOCIATED FAUNA.

During the operation of plankton tow-nets, scoop nets and fish larva traps on the routine, inshore and other stations of the pilchard research programme, numbers of eggs, larvae and early juvenile stages of other species of fish were caught. Although it has not so far been possible to make other than a broad study of these, a general examination has given an indication of the commoner forms found in association with the young stages of the pilchard. It is hoped that detailed examination of these collections will yield a great deal of information on the reproduction of the fishes in this area. It is also of considerable importance to know the life histories of all the commoner species which compete with or prey upon the pilchard in the same environment.

Together with developmental stages of fishes collected in plankton nets, larva traps, etc. large numbers of adult fish were caught by various means in the area of pilchard research. Over a period of years it is hoped that a clear picture of all the fishes living in association with the pilchard in the same environment will be obtained in this way.

The various means used consisted of the use of a 90 ft. otter trawl at least once during every round of routine stations. This not only gave a good picture of the demersal species in the area but frequently demonstrated the presence of pelagic fish in large numbers as well. Apart from the otter trawl, a beam trawl was used in the shallow waters near the coast and set-nets or gill-nets were used in areas protected by law, often with very good results. The N200 tow net was used from time to time but rarely caught young fish. The explosive method of catching juvenile stages of pilchards often yielded large catches of young and adult fish of other species. During a routine cruise lines were trolled between stations whenever possible and small numbers of fish were caught from time to time. Also, handlines were used on station and whenever the ship was not going ahead during the day or night. Considerable numbers of fish were collected in this manner.

From the developmental stages obtained by means of plankton tow-nettings, etc., and from the fishes collected by the methods mentioned above, during the first year of research, the following species may be said to be of importance in relation to the general environment of the pilchard:—

(i) Maasbanker, *Trachurus trachurus* (Linn).

The eggs, larvae and juveniles of this important commercial species were found in the area of routine research stations; eggs and larvae mainly offshore in spring and summer and juveniles in autumn and winter at the inshore stations as well, showing the fish to be a summer spawner.

Maasbankers were frequently caught in trawls in the vicinity of station E, and are regularly caught by the commercial trawlers on the West ground centred around a point 45 miles north west of Cape Town. In general, maasbankers caught offshore in deeper water were large, sexually mature and in the summer months frequently possessed gonads in an active or ripe condition. Those caught by the pilchard boats during all periods when pilchards were not available in areas of shallower water close inshore were generally very much smaller, often immature and usually possessed inactive gonads. This indicates a possible offshore migration of the larger, sexually mature maasbankers to deeper waters in summer for spawning purposes. Although comparatively few large maasbankers were seen in commercial catches, they were caught in Saldanha Bay and in St. Helena Bay during the winter months, indicating a probable return migration inshore during this period.

Maasbankers were observed and caught in large numbers in winter in Saldanha Bay where they were seen to be very actively preying upon juvenile pilchards and anchovies. Large shoals were seen alongside the ship taking a very heavy toll of young pilchards and anchovies attracted to the ship's side by a light. Examination of many maasbanker stomachs at sea, however, revealed that a very great proportion of the diet of the larger individuals consisted of crustacea such as amphipods and euphausiids.

The maasbanker is a fish of considerable economic importance (over 100,000 tons caught annually) and is caught mainly when pilchards are not available, for reduction to meal and oil, for canning and to a much smaller degree for local consumption and bait.

Sampling of maasbankers is carried out whenever possible during the course of routine pilchard work ashore and full records are kept. It is hoped that over a period of time it will be possible to make a full study of the life history of this species.

(ii) Anchovy, *Engraulis japonicus* (Houttuyn)

Eggs were not found at the routine stations but were collected from inshore stations in St. Helena Bay in small numbers in the month of November. Larvae were found in small numbers at the routine stations during the summer months, but post-larvae and juveniles were found inshore in St. Helena Bay and in Saldanha Bay in large concentrations in late summer, autumn and winter. Shoals of juveniles were frequently found in association with young pilchards of similar size.

It seems unlikely that any part of the area investigated is anything but an incidental spawning area for anchovies, yet the main spawning area is probably not very far distant judging by the fact that so many post-larvae and juveniles were found in the St. Helena Bay area.

Adult anchovies were frequently seen in very large shoals in the routine and inshore station areas. They were observed mainly in the spring and summer months and only very rarely in winter. Occasionally they were caught together with pilchards in the commercial nets, but being smaller and more slender fish than the average pilchard they generally went through the meshes of the nets. Anchovy shoals appeared to move about a great deal and it is possible that they move away entirely from the St. Helena Bay area in winter. They were observed in Table Bay, False Bay and off Cape Agulhas in the summer months.

Like the Californian species, the Cape anchovy may be a latent fishery resource of some importance and initial technological investigation has revealed it to be a food of the highest quality. Although catching of this species would almost certainly involve the use of nets of smaller mesh than those used for pilchards—a difficulty relative to pilchard conservation in the pilchard fishing area—further investigation of the anchovy from a commercial point of view might be very well worth while.

(iii) Round Herring, *Etrumeus micropus* (Schlegel).

A small number of developmental stages was obtained during the year, and large numbers of adult round herring were present in St. Helena Bay in spring and summer and as much as 50 tons were recorded in the total landings of the pilchard boats for one night's fishing. They were frequently caught in the nets mixed with pilchards and were used in the same manner by the factories for reduction into oil and meal. They were distinguished by the local fishermen as a different species and were commonly known as the "big-eyed sardine".

This species was previously not recorded south of Knysna on the East coast but it appears that its range extends much further south. It is possible that shoals congregate in the vicinity of the Cape in the summer months, for purposes of spawning.

Examination of the stomach contents of a small number of round herring showed that amphipods

and euphausiids had been eaten, but further investigations may show that its feeding habits are similar to those of the pilchard. The structure of the gill-rakers certainly points to this.

(iv) Snoek, *Thyrsites atun* **(Euphrasen).**

Adult snoek were caught on handlines on the outer line of routine stations during every month of the year, and in large numbers in the whole area of investigation during the winter months of June and July. From examination of stomach contents it appeared that snoek fed almost exclusively on pilchards in this area; snoek, together with sea birds such as gannets and cormorants, were probably the most active of the natural predators of the pilchard.

Because of its importance as a pilchard predator it is of interest to give some facts about its occurrence and some indications of its migration. The commercial fishing season for snoek in the Union occurs from when the shoals appear off the West coast in the vicinity of Port Nolloth in April and May and move south to the Cape during June and July. After July the snoek virtually disappear from the fishing grounds.

The commercial season for snoek in South-West Africa is mainly during November, December and January but may continue on a smaller scale until as late as May. At the beginning of the South-West African season the condition of the snoek is usually poor in that they contain very little fat and are lean in appearance. At this time their gonads are small and undeveloped. Later in the season, however, a marked change becomes noticeable and the snoek rapidly fill out and become fat and the gonads develop.

There is direct evidence of connection between the S.W. African and the Union snoek populations. In the past large numbers of snoek were tagged in S.W. African waters by this Division (Marchand, 1934). The majority were tagged in the vicinity of Walvis Bay and a total of 16 recoveries were made, all of which showed that the snoek had moved south from S.W. Africa to the Cape. The greatest distance covered was between Pelican Point and Simonstown, a distance of approximately 880 miles. The following records illustrate this southerly movement well:—

(*a*) No. 2317—Tagged 23rd November, 1934, off Pelican Point, S.W. Africa. Recovered April, 1935, off Shell Bay Point, St. Helena Bay.

(*b*) No. 1789—Tagged 16th November, 1934, off Pelican Point, S.W. Africa. Recovered 4th June, 1935, off Thorn Bay.

Towards the end of the Cape snoek season, i.e. in the months of June or July, there is a very marked tendency for snoek to move offshore in a westerly direction, and it is in this direction that the final disappearance takes place. At this time the snoek are in fine condition and gonads are generally ripe.

During the month of October a sexually-active male snoek and a female snoek with ripe and running roes were caught on the trawling grounds off Cape Town (approx. 45 miles N.W. of Table Bay). Artificial fertilization was successfully carried out at sea and the development up to the time of absorption of the yolk sac obtained (De Jager, 1950).

Young snoek of total length approximately 10 cm. were obtained in the Cape Town dry dock in very large numbers in January. Small, so-called " China Snoek ", of total length circa 30 cm. were obtained in shoals in winter and summer in Saldanha Bay. A detailed examination revealed that these were young *Thyrsites atun* and not any related species of smaller size. These young snoek were found to be feeding very heavily on young pilchards and anchovies.

In the light of this data it seems likely that the snoek which arrive in the Walvis Bay–Cape Cross area of S.W. Africa in summer, are in poor condition as a result of recent spawning. They remain in this area most of the summer and during this time feed voraciously on pilchards and build up their condition. At the same time gonad development takes place. Then in late summer the shoals move south along the coast, reaching St. Helena Bay in early autumn and the Cape in late autumn and winter. They feed actively on pilchards wherever possible on the journey. Then in late winter and early spring they move west from the Cape and out to deeper water where spawning takes place. After spawning the return movement in deeper water back to S.W. Africa takes place.

Apart from the evidence from tagging which proves the southerly migration of snoek, vast shoals have been seen close inshore along the S.W. African coast, moving south and feeding actively on pilchards.

That reproduction takes place in deep water off the Cape has been shown by the collection of ripe and running fish on the trawling grounds and

the presence of young fish in Table Bay and in Saldanha Bay. The return migration north has not yet been proved, but, judging by the presence of numerous spent fish along the outer line of routine stations, such a movement is very likely. It is probable that spawning takes place in an extended area approximately 50 miles offshore from Cape Point northwards, perhaps as far as Walvis Bay.

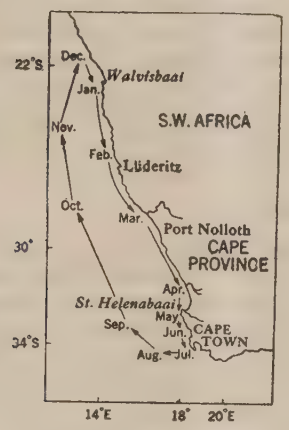

FIG. 7 MIGRATION OF SNOEK

Trigonometrical Survey, 1954. Government Printer, 1954

The pilchard has been found to be the main food of the snoek both in S.W. African and Union waters. The populations of S.W. African and Union snoek have been shown to be the same and their extensive migrations have been proved. The question now arises as to whether a similar relationship exists between the S.W. African and Union populations of pilchards. No tagging of pilchards has so far been possible, but southerly movements of pilchard shoals are known to occur off S.W. Africa and from the St. Helena Bay area as far as Cape Agulhas. It seems possible that a migratory cycle similar to that of the snoek may exist in the pilchard.

(v) Other Pelagic Species.

The Skipper or Saury, *Scombresox saurus* (Walb.), was frequently seen when attracted to the ship's side by means of a light, but mainly on the outer stations A, B and C. Large numbers ranging from fish 2 ins. to over 12 ins. in length were seen to congregate at the surface where their snake-like movements and short jumps appeared at times to make the water boil. This species was far more common further to the west in warmer water, although juveniles occurred in fair numbers close inshore.

Of the bathypelagic species, the Lantern Fishes, *Myctophum humboldti* (Risso), *M. cocco* (Cocco) and *Maurolicus pennanti* (Walb.), were by far the most important. *Myctophum humboldti* was seen at the surface at night in varying numbers at most of the routine stations throughout the year, but *M. cocco* was rare. *Maurolicus pennanti* appeared from time to time in large numbers mainly at the outer stations. Larvae and juveniles of *Myctophum* and *Maurolicus* were collected in plankton tow-nettings.

On rare occasions juveniles of Bluefin Tunny, *Thynnus thynnus* (Linn.), were taken. Schools of adult tunny were also occasionally seen but always at the outer stations. Yellowtail, *Seriola lalandi* (Val.), were rarely seen and occasionally caught while trolling.

(vi) Demersal Species.

The post-larvae and juvenile stages of Stockfish, *Merluccius capensis* (Castelnau), were frequently obtained and occurred mainly in the summer months. Examination of stockfish stomachs showed that pilchards were eaten in large numbers whenever encountered.

Young stages of the West Coast Sole, *Austroglossus microlepis* (Bleeker), were found from time to time at the routine stations. This species was once abundant in the St. Helena Bay area but has almost disappeared in recent years. The cause of this disappearance is unknown, but is certainly reflected in the small numbers of larvae obtained in plankton during routine tow-nettings throughout the year.

Various developmental stages of the Gurnard, *Trigla capensis* Cuvier, Jacopever or Sancord, *Helicolenus maculatus* (Cuvier), true Jacopever, *Sebasticthys capensis* (Gmelin), and John Dory, *Zeus faber* Linn., were found at the routine stations. The juveniles occurred in fish larva trap catches.

(vii) Inshore Species.

In the protected areas along the coast between Lamberts Bay and Saldanha Bay, evidence of large populations of small fishes was found. Young stages of these were obtained in inshore plankton nets, and the adult forms by means of explosive charges and scoop nets.

Extensive shoals of Silverside, *Atherina breviceps* Cuv., known locally as Vlei Sardine (although non-clupeoid), were encountered, mainly in St. Helena Bay and in Saldanha Bay. Large shoals were usually accompanied by numerous cormorants, *Phalacrocorax capensis* and *P. neglectus*, which caught and consumed the fish at a great rate. Young pilchards were frequently seen in association with *Atherina* particularly in Saldanha Bay. Stomachs of *Atherina* examined from time to time contained mainly diatoms, together with small numbers of copepods, zooea crab larvae, etc. This species was shown to be a filter feeder competing for food with young pilchards in the same area.

Spawning of *Atherina* took place in summer and development appeared to take place either close inshore or right in protected areas such as Langebaan.

Numbers of Whitebait, *Gilchristella aestuarius* (Gilchrist and Thompson), also sometimes known as Vlei Sardine although very different from *Atherina*, were found to be present mainly within the landlocked areas of Saldanha Bay and Langebaan. Shoals of whitebait were sometimes found in association with young pilchards, and were also filter feeders competing with them for food. Stomach contents varied with the area in which the fish were caught and were generally found to be representative of the plankton around them. Food organisms included the larger diatoms such as *Coscinodiscus*, small copepods, lamellibranch larvae, polychaete larvae, zooea crab larvae, etc. No information on reproduction was obtained.

Mullet or Harders, *Liza ramada* (Risso), were present in the pilchard area. Extensive shoals of adult mullet were frequently found in St. Helena Bay in association with shoals of adult pilchards, but like the pilchards, appeared to move about a great deal. Smaller shoals of young mullet were sometimes found close inshore in the area and inside Saldanha Bay. Examination of stomach contents showed similar food to that of the pilchard.

In St. Helena Bay during the summer months large numbers of the active post-larvae and juveniles of the Cape Rockling, *Gaidropsarus capensis* (Kaup.), were seen. When a light was put over the ship's side large numbers frequently congregated and resembled young skippers due to their bright silver colouration and snake-like movements on top of the water. These young stages were not certainly identified until a number were allowed to develop into adult form in the hatchery of the shore laboratory. As soon as the final metamorphosis had taken place the habit of swimming about actively at the surface was dropped and they went to the bottom and lay hidden in corners or under rocks and only appeared when short dashes were made for food.

Judging by the number of young seen, this species must be very common in the area.

Late larvae and juveniles of the Sandcord, *Gonorhynchus gonorhynchus* (Linn.), were common in St. Helena Bay and in Saldanha Bay in the summer months. Although frequently mixed with young pilchards, they did not move together in tightly packed shoals but seemed to scatter loosely amongst the other young fish.

(viii) Invertebrates.

Results of the study of the plankton of the area will be described in detail elsewhere, but the presence of a rich phytoplankton in the St. Helena Bay area was of great importance relative to the feeding of adult pilchard shoals. Amongst the zooplankton, copepods were important as a food of adult and juvenile pilchards, while euphausiids and amphipods comprised the major food of the adult maasbanker. Large numbers of larval stages of polychaetes were frequently seen in association with young pilchards.

Apart from the plankton, however, the most abundant invertebrate found throughout the area of routine and inshore stations, and inside all the protected bays, was the Squid, *Loligo reynaudi*. Large numbers of squid were regularly seen throughout the year, but appeared to move about considerably. As no special study was made of squid, regular samples were not taken, but they were frequently caught from the ship's side with the aid of a light by means of jiggers manipulated by the crew whenever bait was required. They were present in trawl nettings at the outer stations and in Saldanha Bay throughout the year. They appeared to move in shoals of a dozen or more and were capable of short bursts of high speed when catching food. From hunting operations witnessed from the ship's side and from stomach contents examined, the squid was seen to be a voracious feeder on any small fish including young pilchards.

At present squid are caught mainly by the commercial trawlers and are sold largely for bait and to a small degree for human consumption. It is felt that the squid could be caught and

marketed on a much larger scale than it is at present, and that from it a refined product could be made available as a first class sea food.

(ix) Birds.

No mention of the fauna associated with the pilchard would be complete without some reference to what may be conveniently termed the guano birds of the West coast. These include the Cape Cormorant or Trek Duiker, *Phalacrocorax capensis*, the Cape Gannet or Malgas, *Sula capensis*, and the Jackass Penguin, *Spheniscus demersus*.

Cape cormorants and gannets were observed in flocks of thousands actively fishing on shoals of pilchards in St. Helena Bay. Feeding individuals were shot and found to be packed with pilchards. A shoal of pilchards moving across the bay would be constantly subjected to a bombardment of fishing gannets diving from above, while the cormorants dived from the surface and penguins darted in from the edge. This continued from dawn till dusk.

Work on a small scale on the feeding of these birds was started during the year, but observation to date has already shown that they are amongst the most important of the natural predators of the pilchard.

(x) Remarks.

It is of considerable interest to note the similarity between the marine fauna of the west coast of South Africa and the fauna of the Californian coast. In most of the species mentioned above, there is an equivalent in Californian waters. This is well illustrated in the following list:—

California.	*South Africa.*
Sardine, *Sardinops caerulea*	Pilchard, *Sardinops ocellata.*
Jack Mackerel, *Trachurus symmetricus*	Maasbanker, *Trachurus trachurus.*
Anchovy, *Engraulis mordax*	Anchovy, *Engraulis japonicus.*
Skipper, *Colalabis saira*	Skipper, *Scombresox saurus.*
Hake, *Merluccius productus*	Stockfish, *Merluccius capensis.*
Rockfish, *Sebastodes* spp.	Jacopever, *Sebasticthys capensis.*
Smelt, *Atherinopsis californiensis*	Vlei Sardine, *Atherina breviceps.*
Tunny, *Thunnus thunnus*	Tunny, *Thunnus thunnus.*
Lantern Fishes, *Myctophum* spp.	Lantern Fishes, *Myctophum* spp.
Squid, *Loligo opalescens*	Squid, *Loligo reynaudi.*

The most striking equivalent is naturally that of the California sardine and the South African pilchard. There is no doubt that many more similarities will be found in comparing the fauna of the two areas, particularly in relation to the plankton, but apart from these biological considerations it is hoped that it will be possible to make a detailed comarison of penvironmental conditions.

12. ACKNOWLEDGMENTS.

From the outset the Pilchard Research Programme and its execution has been a striking example of the successful co-operation of a number of specialised teams working closely together. For this reason full acknowledgment is made to every member of the staff of the Division including those in the offices, the laboratories and the ships.

It is particularly desired to thank Dr. J. M. Marchand, *M.B.E.*, Director of Fisheries, for help and guidance; Commdr. R. L. V. Shannon, *O.B.E.*, Master, R.S. "*Africana II*", and Mr. W. Taylor, *M.B.E.*, Fishing Technologist, for their constant enthusiastic help; Mr. A. J. Clowes, M.Sc., Hydrologist, for figures and help with the hydrology; and Messrs. B. de Jager, M.Sc., C. Nepgen, B.Sc., and F. Grewe, M.Sc., members of the biological section who were very closely associated with the work, and finally Prof. J. H. Day, *D.F.C.*, of the University of Cape Town, for critical reading of the paper and helpful advice.

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PLATE I

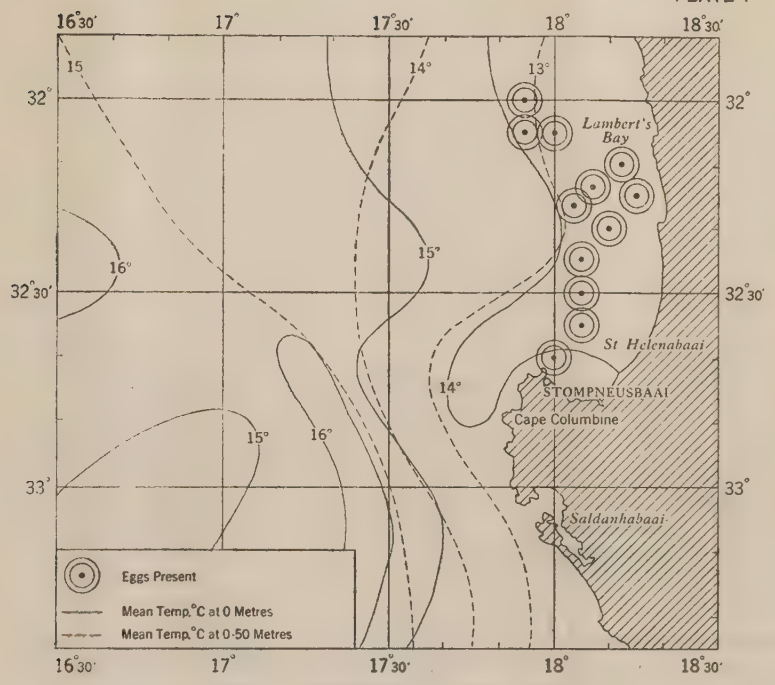

FIG. I PILCHARD EGGS : WINTER 1950

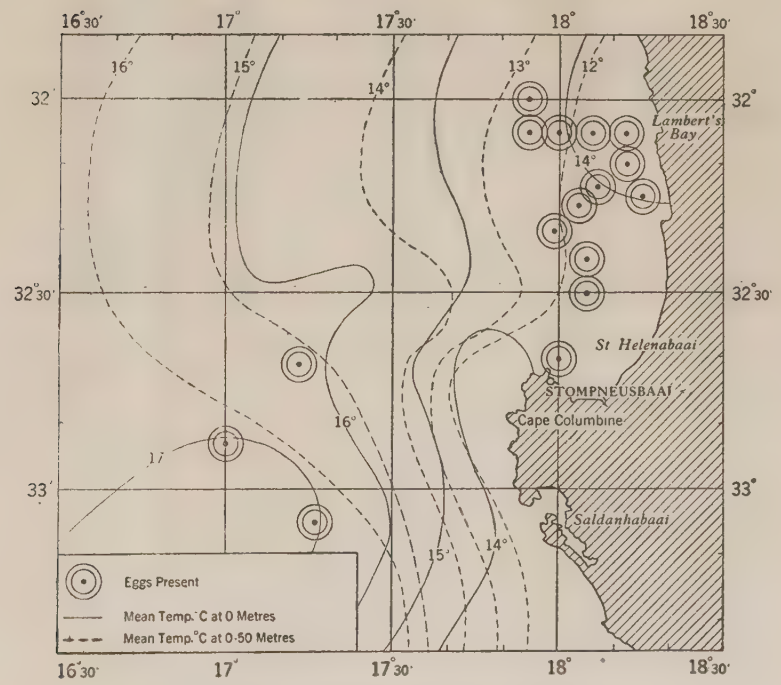

FIG. II PILCHARD EGGS : SPRING 1950

Trigonometrical Survey, 1954

Government Printer, 1954

PLATE 2

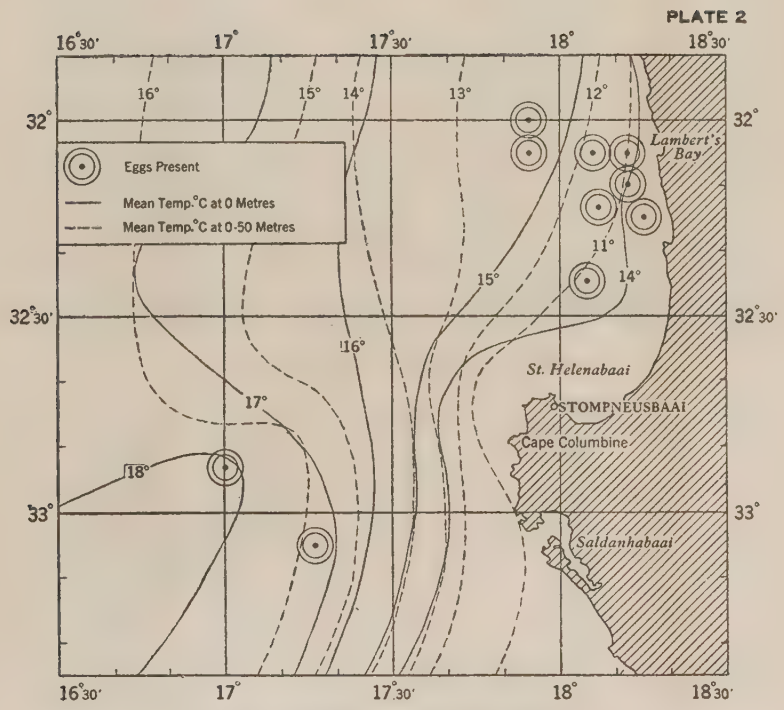

FIG. III PILCHARD EGGS : SUMMER 1950-51

Trigonometrical Survey, 1954. Government Printer, 1954.

PLATE 3

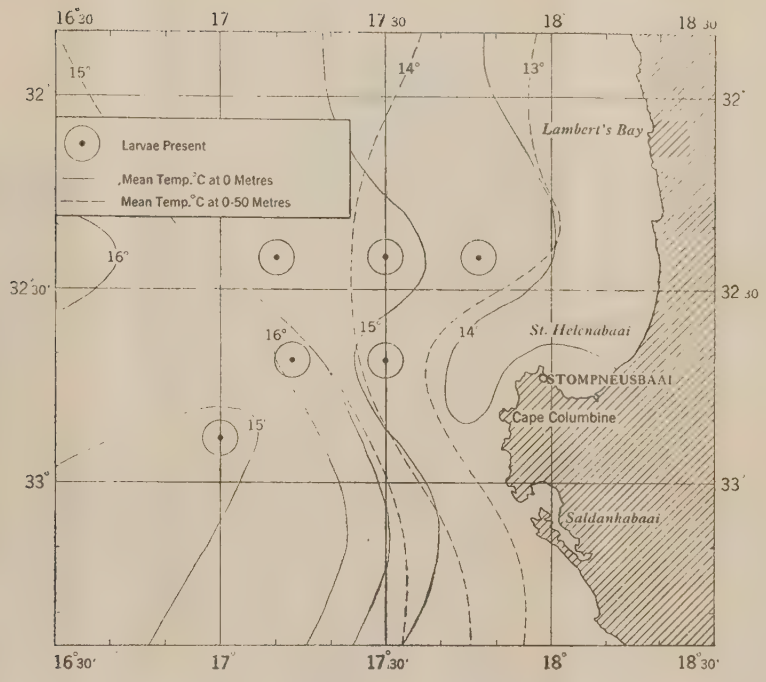

FIG. IV PILCHARD LARVAE : WINTER 1950

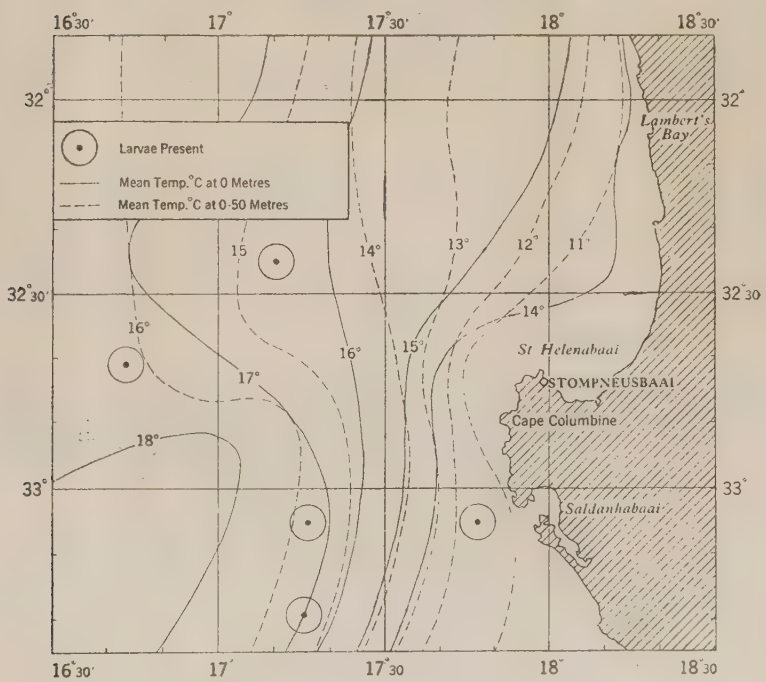

FIG. VI PILCHARD LARVAE : SUMMER 1950-51

Trigonometrical Survey, 1954 Government Printer 1954

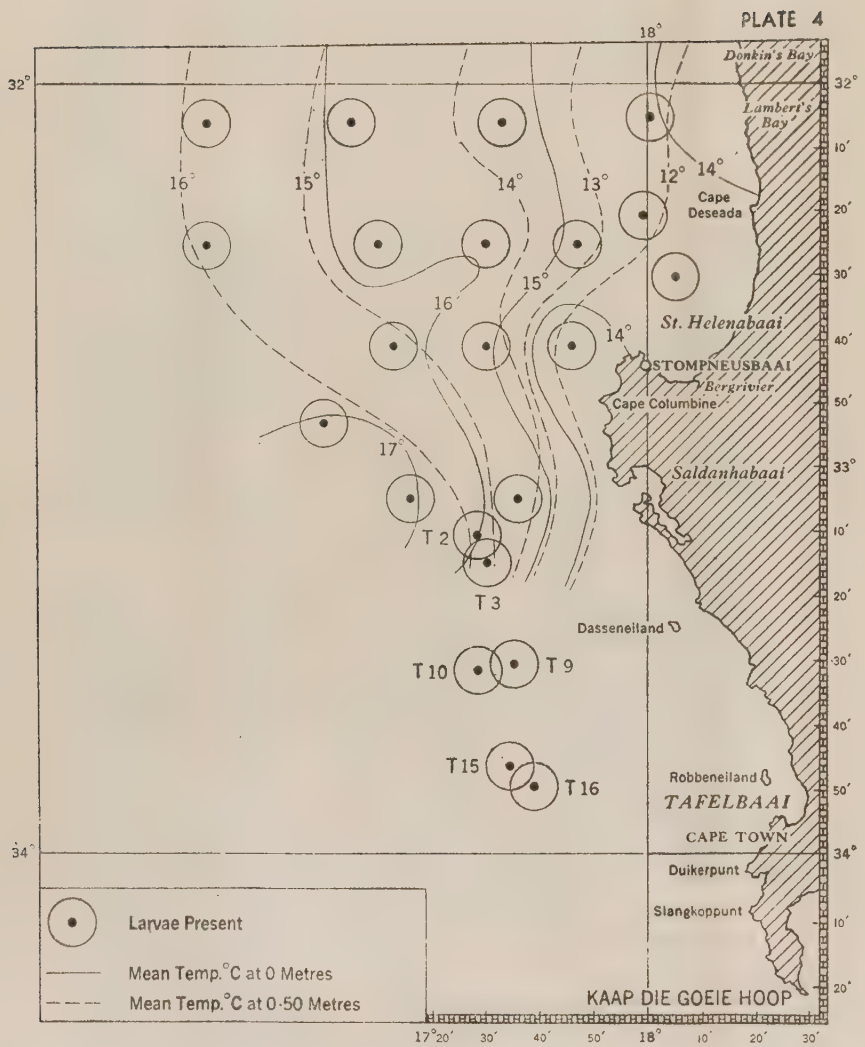

FIG. V PILCHARD LARVAE : SPRING 1950

Trigonometrical Survey, 1954. Government Printer, 1954

PLATE 5

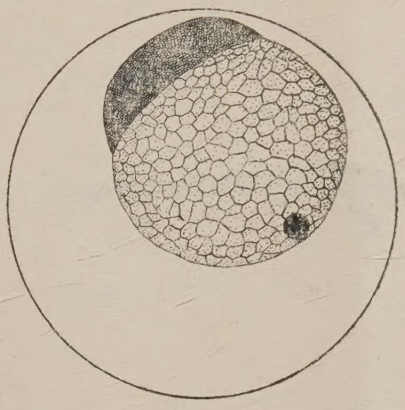

FIG. I.—PILCHARD OVUM: DIAM. 1·48 MM.

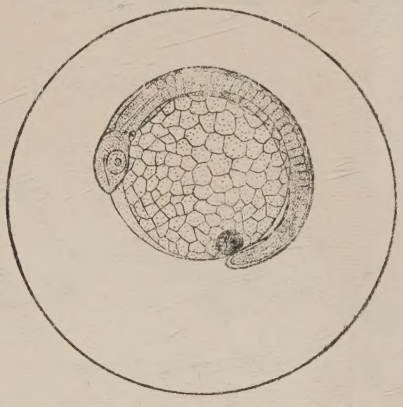

FIG. II.—PILCHARD OVUM: DIAM. 1·75 MM.

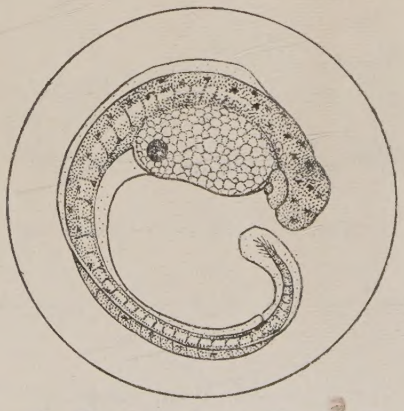

FIG. III.—PILCHARD OVUM: DIAM. 1·80 MM.

PLATE 6

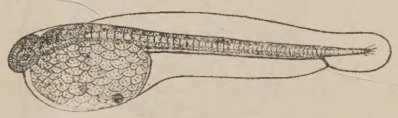

FIG. I.—LARVA, 3·6 MM.

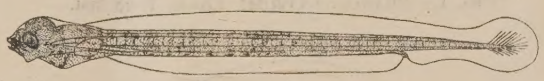

FIG. II.—POST-LARVA, 10·6 MM.

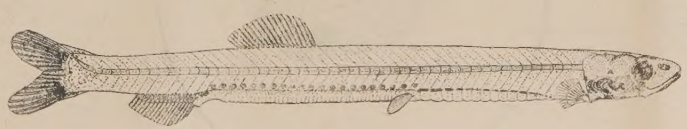

FIG. III.—POST-LARVA, 23·5 MM.

FIG. IV.—JUVENILE, 42 MM.

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